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USER'S GUIDE FOR SKETCH

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INTRODUCTION

This software package solves the hidden line problem, that problem in computer graphics which addresses the removal of hidden parts from images of solid objects. Hidden line removal is necessary to create a realistic image. As an illustration, compare figure 1 (before solution) with figure 2 (after solution).
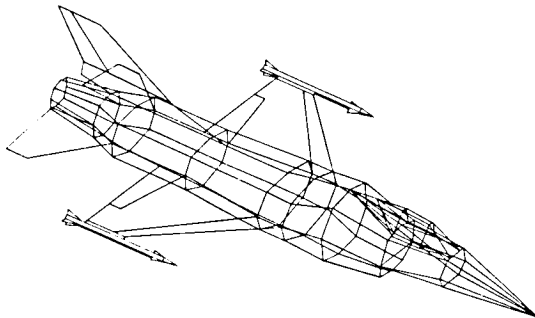
Before solution
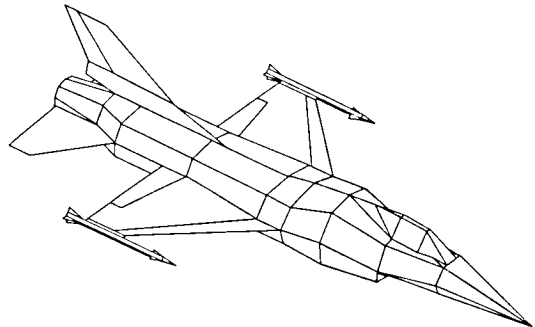
After solution

Fig. 1

Fig. 2

This guide will discuss the topics of:

1. How to decompose figures into appropriate input elements and how to "feed" these elements to the hidden line package.

2. How to incorporate the package into a FORTRAN program.

3. How to install and run the package on the user's computer system.

INPUT ELEMENTS AND HOW TO "FEED" THEM TO THE HIDDEN LINE PACKAGE

The input elements to the hidden line package are either line segments or planar polygons. The polygons can be n-sided concave or convex and can have concave or convex holes.

The input elements are described in terms of their endpoints (in the case of line segments) or vertices (in the case of polygons). It is these endpoints or vertices, in the form of (x, y, z) triplets, that are input to the hidden line package.

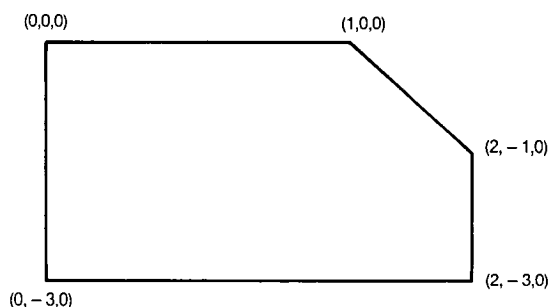As an example, note the following pentagon:

Fig. 3

The triplets may be input to the package in either a clockwise (A) or counter-clockwise (B) manner:

$$(A) \quad (0,0,0) \quad (1,0,0) \quad (2,-1,0) \quad (2,-3,0)$$
$$(0,-3,0) \quad (0,0,0)$$

or

$$(B) \quad (2,-3,0) \quad (2,-1,0) \quad (1,0,0) \quad (0,0,0,)$$
$$(0,-3,0) \quad (2,-3,0)$$

In a given plot, composed of many such figures, any combination of clockwise and counter-clockwise may be used. It is not necessary that all figures be either clockwise or counter-clockwise.

Note in the above examples that the last point and the first point are the same. This is done to remove the difficulty that arises when the polygon has several holes.

Consider the next example, a square with a triangular hole:

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(0,1,0)   (1,1,0)

(.3,.7,0)

(.5,.4,0)

(.2,.4,0)

(0,0,0)   (1,0,0)

Fig. 4

This is a polygon of seven edges and is input in the following manner:

(0,1,0) (0,0,0) (1,0,0) (1,1,0)
(0,1,0) (.2,.4,0) (.5,.4,0) (.3,.7,0)
(.2,.4,0)

Nine input triplets are required to "close-up" each sub-figure.

The actual method for inputting the triplets to the hidden line package is by means of subroutine SKETCH. The calling sequence for SKETCH is as follows:

CALL SKETCH (x,y,z,NTRP,NC)

where

x, y, z   are dimensioned arrays to hold the triplets

NTRP   is the number of triplets in a given call to SKETCH

NC   is a flag: must be set to 1 for the last call to SKETCH for a given plot

                   must be set to 0 in all other cases

As an example, consider figure 4, the square with a triangular hole. This figure will require one call to SKETCH. The x, y, and z arrays must be dimensioned at least nine each, and will appear as follows:

x(1) = 0	y(1) = 1	z(1) = 0
x(2) = 0	y(2) = 0	z(2) = 0
x(3) = 1	y(3) = 0	z(3) = 0
x(4) = 1	y(4) = 1	z(4) = 0
x(5) = 0	y(5) = 1	z(5) = 0
x(6) = .2	y(6) = .4	z(6) = 0
x(7) = .5	y(7) = .4	z(7) = 0
x(8) = .3	y(8) = .7	z(8) = 0
x(9) = .2	y(9) = .4	z(9) = 0

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NTRP, the number of triplets for this call to SKETCH, is nine. Since this is the only and last call to SKETCH, NC is set equal to 1.

Therefore:

CALL SKETCH (x,y,z,9,1)

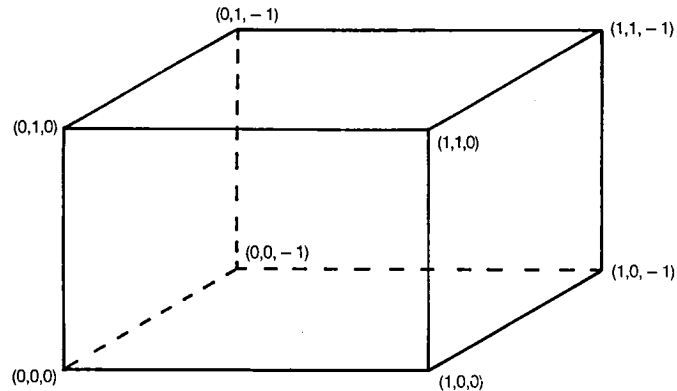Now consider the simple box in figure 5.

Fig. 5

This figure will require six calls to SKETCH, one for each face of the box.

The front face is composed of the following triplets:

(0,1,0) (0,0,0) (1,0,0) (1,1,0)
(0,1,0)

The arrays x, y, and z must be each dimensioned at least five and will appear as follows:

x(1) = 0	y(1) = 1	z(1) = 0
x(2) = 0	y(2) = 0	z(2) = 0
x(3) = 1	y(3) = 0	z(3) = 0
x(4) = 1	y(4) = 1	z(4) = 0
x(5) = 0	y(5) = 1	z(5) = 0

NTRP, the number of triplets for this call to SKETCH, is five and since this is not the last call to SKETCH, NC is set equal to 0. So:

CALL SKETCH (x,y,z,5,0)

Each of the remaining five faces will be input in a similar way. On the sixth and final call to SKETCH, NC will be set to 1.

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This figure can also be referred to as a figure containing six input elements.

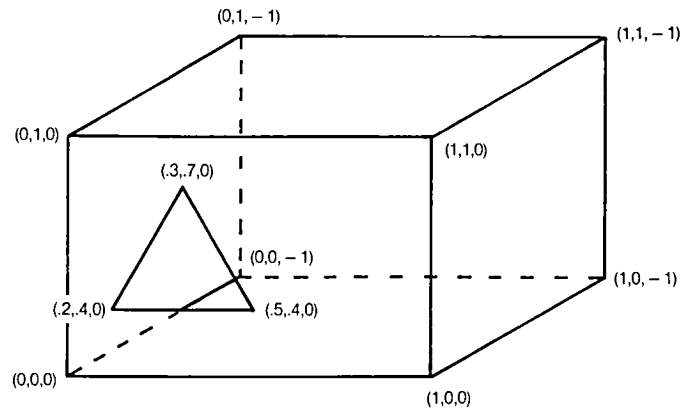Figure 6, a box with a hole cut in the front face, is also a figure of six input elements.

Fig. 6

The front face would contain nine input triplets (as described in a previous example) and therefore the x, y, and z arrays would each be dimensioned at least nine. NTRP, the number of points in the call to SKETCH for the front face, would be nine. For each of the other faces, NTRP would be five.

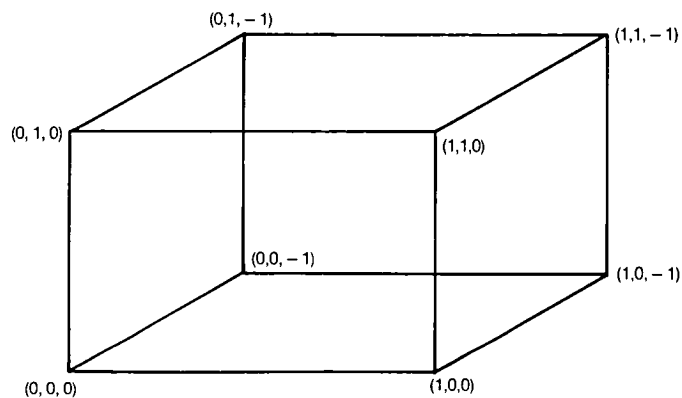Now consider a transparent box, figure 7.

Fig. 7

This figure is a composite of 12 input elements, 12 line segments. It will require 12 calls to SKETCH, with the x, y, and z arrays each dimensioned at least 2 and NTRP equal to 2. For the bottom front edge:

$$x(1) = 0 \qquad y(1) = 0 \qquad z(1) = 0$$
$$x(2) = 1 \qquad y(2) = 0 \qquad z(1) = 0$$

CALL SKETCH (x,y,z,2,0)

In a similar manner all 12 of the edges will be input to SKETCH.

Note that on the 12th call to SKETCH, NC must be set equal to 1.

In the appendix, a sample figure is decomposed into input elements and "fed" to SKETCH by a sample user program. The resulting plots are also shown.

INCORPORATING THE HIDDEN LINE PACKAGE INTO THE USER'S FORTRAN PROGRAM

The programmer writing the FORTRAN code that calls the hidden line package must be aware of certain information needed by the package and must also provide information to the plot output device.

The hidden line package requires two named common blocks that must be set up in the calling program. The first is:

COMMON/GO/WORK(ICORE)

where:

ICORE = (25 + 5 * MNE + 4 * MNP)* NELEM .

MNE = Maximum number of edges that any one polygon has.

MNP = MNE + 2 + 2 * n; where n is the number of holes, if any.

NELEM = Total number of elements in one entire plot.

The second common block is:

COMMON/SCALAR/SCF, PSI, PHI, THETA, MNE, DV, MNP, ICORE

where:

SCF = Scaling factor (units/inch) for Plot Output Device. Note: if SCF is negative, a transparent plot with no hidden lines will be produced.

PSI, PHI, THETA = The Eulerian angles (degrees) about the x-, y-, and z-axes. (See fig. 8.) The order of rotation is ψ-ϕ-θ.

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MNE = (INTEGER) The maximum number of edges that any one polygon has.

DV = A positive number that represents the distance of the viewer from the plane of the plot.

MNP = (INTEGER) Defined above.

ICORE = (INTEGER) The total core needed by the hidden line package for data.

For data storage, ICORE is defined above.

Axis system convention and
Eulerian angles definition

ψ = PSI
ϕ = PHI
Θ = THETA

Think of unscrewing a nut. Keep it consistent with this idea for direction of axis and sign of angle.
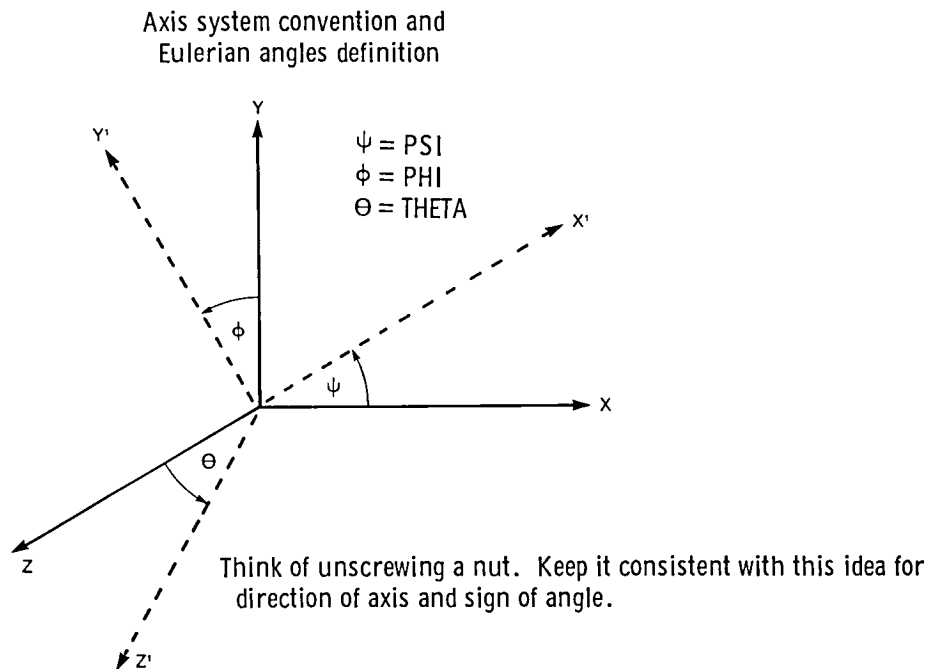
Fig. 8

The package does not assume any environmental coherence, so, in the interest of efficiency, it might be a good idea in some cases to use a pre-processor. This preprocessor should eliminate whole planes by looking at the normals to the planes, in the case of closed polyhedra or any combination of closed polyhedra.

The hidden line package assumes that the output unit is a CALCOMP format tape or disk file and uses standard CALCOMP commands. If another type device is to be used, modifications will be needed to the hidden line package subroutine PLT. But these modifications will be simple.

The user must take responsibility for opening and closing the plot

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device. The device must be opened before the first call to SKETCH and closed after the last call to SKETCH.

Using the standard CALCOMP commands as an example there would be:

CALL PLOTS (0,0,1)

and

CALL PLOT (0,0,999)

respectively.

Requirements will, of course, vary from installation to installation. The sample in the appendix was created on a CDC Cyber 6500 using the Network Operating System (NOS).

Note: If the polygons are very warped, then errors could occur. Also, the algorithm assumes at least 32-bit integers and floating-point words.

ERROR CODES

The hidden line package returns error codes after the final call to SKETCH. The codes are found in NC of the SKETCH calling sequence and have the following definitions:

     0 = Normal return

    -1 = Incorrect storage allocation in the array work. The correct storage allocation is placed in ICORE by SKETCH.

    -2 = DV (distance from viewer) in common scalar is incorrect. SKETCH places the correct value in DV.

    -3 = Both DV and storage allocation are in error. SKETCH places the correct values in ICORE and DV.

INFORMATION FOR INSTALLING AND RUNNING THE PACKAGE ON THE USER'S SYSTEM

The hidden line package is a FORTRAN IV program of about 1800 source cards. It occupies approximately 9500 + ICORE decimal words on a CDC 6500 computer, exclusive of system overhead.

The package uses the standard CALCOMP subroutines, as defined in the CALCOMP manual.

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In this example, a hexagonal cylinder is decomposed into input elements and relayed, via a FORTRAN calling program, to the hidden line package. The resulting plots are also shown. The origin is at the center of the figure.

The hexagonal cylinder, without its x, y, z coordinates, is shown in figure 1. It is made up of six four-sided polygons and two six-sided
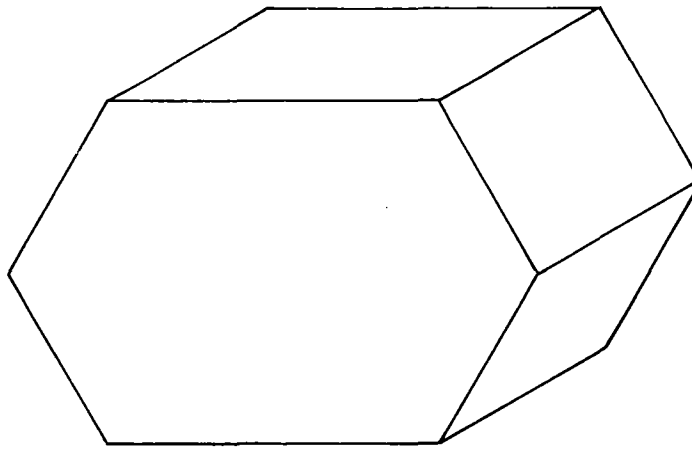

Fig. 1

polygons (the top and bottom), for a total of eight faces. The input x, y, and z coordinates for each face are as follows:

FACE 1				FACE 2				FACE 3		
$\frac{x}{-5}$	$\frac{y}{0}$	$\frac{z}{3}$		$\frac{x}{-3}$	$\frac{y}{2}$	$\frac{z}{-3}$		$\frac{x}{3}$	$\frac{y}{2}$	$\frac{z}{-3}$
-3	2	3		-3	2	3		5	0	-3
-3	2	-3		3	2	3		5	0	3
-5	0	-3		3	2	-3		3	2	3
-5	0	3		-3	2	-3		3	2	-3

FACE 4				FACE 5				FACE 6		
$\frac{x}{5}$	$\frac{y}{0}$	$\frac{z}{-3}$		$\frac{x}{3}$	$\frac{y}{-2}$	$\frac{z}{3}$		$\frac{x}{-5}$	$\frac{y}{0}$	$\frac{z}{-3}$
5	0	3		3	-2	-3		-5	0	3
3	-2	3		-3	-2	-3		-3	-2	3
3	-2	-3		-3	-2	3		-3	-2	-3
5	0	-3		3	-2	3		-5	0	-3

FACE 7 (Front)				FACE 8 (Back)		
x	y	z		x	y	z
-5	0	3		-5	0	-3
-3	2	3		-3	2	-3
3	2	3		3	2	-3
5	0	3		5	0	-3
3	-2	3		3	-2	-3
-3	-2	3		-3	-2	-3
-5	0	3		-5	0	-3

In the FORTRAN program, these coordinates are punched on cards and read into arrays x, y, and z by subroutine READARY. This subroutine also calculates the number of triplets (NTRP) and passes the results to the hidden line package.

In this example MNE (maximum number of edges) is six and NELEM (total number of elements in entire plot) is eight. Therefore, ICORE is calculated as follows:

$$ICORE = (25 + 5 * MNE + 4 * MNP)* NELEM$$
$$= (25 + 5 * 6 + 4 * 8)* 8$$
$$= 696$$

This program creates two hexagonal cylinder plots. One is shown at the Eulerian angles PSI = 20.0, PHI = 10.0, THETA = 3.0 (fig. 2); the other at PSI = -50.0, PHI = -50.0, THETA = 20.0 (fig. 3).
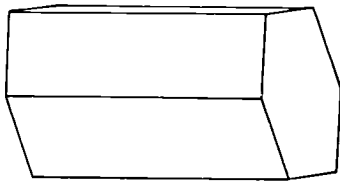

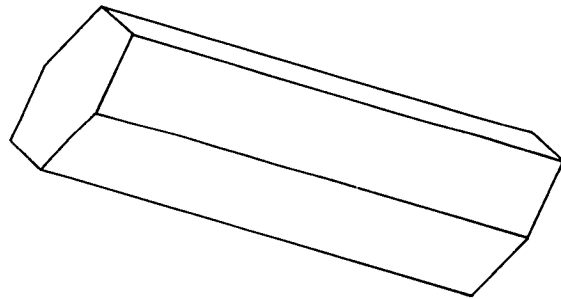Fig. 2   Fig. 3

The x and z coordinates are each multiplied by a constant in order to create a more attractive plot.

The sample user's program along with the SKETCH package is on the accompaning tape.

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16. Abstract

A user's guide for the computer program SKETCH is presented. SKETCH solves a popular problem in computer graphics--the removal of hidden lines from images of solid objects. Examples and illustrations are included in the guide.

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